Participatory evaluation and application of climate smart agriculture practices in mixed smallholder farming systems: a case-study in the semi-arid regions of Kenya

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Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists, September 23-26, 2016, Addis Ababa, Ethiopia

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ABSTRACT (250 words)

In the first phase of the CCAFS Program (Climate Change, Agriculture and Food security), climate-smart agriculture practices (CSAP) were identified and needed to be tested. In the semi-arid maize-growing areas of Kenya, dry-tolerant varieties and maize-legume intercropping appeared as the most appropriate CSAP, and this paper presents farmer's evaluation of these farming systems. During on-station and on-farm trials in Makueni County, participatory evaluation of intercropping systems of five maize varieties and four beans varieties was conducted. In total, 150 farmers participated; they scored each variety on the basis of several phenotypic criteria and provided an overall score for the variety. Results emphasized the complexity of their varieties' perception. In order to explain the overall score by different agronomic and socio-economic factors, a cumulative mixed model effect was estimated, including random effects for each farmer. Dry-tolerant varieties had a significant lower score, as GLP92 for beans and TEGO for maize. Socio-economic factors including age and gender of the participants influenced the overall score of varieties. We demonstrated that farmers who already purchased improved seed tended to give lower score. Finally, an OLS regression allowed exploring the weight of each phenotypic criterion in the overall score of a maize or bean varieties. This analysis revealed that farmer's perception of a good variety is complex and rely on multiple criteria unlike most of the breeding program mainly based on yield oriented indicators.

Keywords: Ordinal regression, Participatory evaluation, maize-bean intercropping, climate-smart agriculture

1 Introduction

In a context of growing population and arable land scarcity, food security in Sub-Saharan Africa (SSA) is a critical challenge in which Maize (*Zea Mays*) has to play a predominant role. Indeed, with more that 23% of land allocated to this crop (FAOSTAT, 2012), maize is a major staple crop in Eastern Africa due to its multiple functionality: residue for both soil and livestock, grain easy to store and transport compare to root crops (De Groot et al., 2013), cash crop (Pingali, 2001) among others. Maize yields are very heterogeneous in Kenya, but the national average by 1.622 Kg/ha (FAOSTAT, 2015) is low and the increase in national production results from area expansion more than in efficiency increase. If this variability reveals the various potential of agro-ecological zones in Kenya, it is also a great indicator of varieties improvement program for the last 25 years. Breeding selection programs has shown great yield improvement potential by focusing on scarce indicators which are generally yield oriented. Nonetheless, after decades of new varieties demonstration, De Groote and Siambi (2005) underlined that a 18 years old variety still count for half of the maize seed sales. The objective of this paper is to understand farmers' preferences, but also to understand how their farming systems or socio-economic characteristics influence this perception.

With the emergence of recent severe food crises, price and climate variability, food security has evolved from a yield perspective to more long-term indicators such as resiliency and adaptation strategy. Ex-ante analysis of climate change impact on agricultural production (e.g. Lobell et al., 2011) has raised the important challenge to design new farming systems which will cope with increasing temperature and climate variability. The challenge to increase by 60% the agricultural production by 2050, due to both demographic and nutritional transitions, has become even more complex due to this climatic uncertainty. As a result of this multidisciplinary reflection, the concept of climate-smart agriculture (CSA) has emerged and can be defined in 3 pillars:

- sustainably increasing agricultural productivity and incomes,
- adapting and building resilience to climate change,
- reducing and/or removing greenhouse gases emissions, where possible.

From an initial focused on the crop level, i.e. climate change's impact on soil fertility and environmental pressure on crop production (see White et al., 2011 for a review), research on climate change evolved to include more socio-economic components. Based on the first CCAFS phase (Climate Change Agriculture and Food Security), climate smart agricultural practices (CSAP) have been identified, and dry tolerant germplasm and different intercropping options appear as a promising pathway to cope with climate change.

While FAO just announced that 2016 will be the "international year of pulses", we focus in this paper on the interaction of maize with common bean (Phaseolus vulgaris). Indeed, benefits of maize-legume rotations (Ojiem et al., 2014) are well-known: legume production fixes nitrogen soil content through symbiotic relationship with soil-dwelling bacteria, so that crops can benefit from it. Sanchez and Jama (2002) underlined that soil fertility decline is one of the major biophysical threat to food security in SSA, and the FAO initiative is clearly oriented toward a better optimization of nutrient flow at crop scale. Therefore, we will pay particular attention to intercropping practices within the whole portfolio of CSA.

2 Materials and methods

2.1 Overview of the approach

Climate change increasingly affects farmers and the livelihood of rural households. Scientists of different disciplines try to improve farmers' resilience by developing CSA technologies: breeders develop drought and stress tolerant varieties, agronomist improve crop management techniques, and social scientists analyse social acceptance and economic feasibility of these CSA options. At the same time, rural institutions are very important to farmers, in particular agricultural extension, seed systems, rural finance, input and output markets, information technology (especially mobile phones) and, relatively new, insurance.

During on-station and on-farm trials, scientists interact with farmers and suggest new technologies. Farmers evaluate those and provide feedback to the scientists. Where needed, rural institutions need to be brought on board, to make sure there is an enabling environment for the new technologies to take off. Scientists then fine-tune the technologies, which farmers then adopt and adapt, increasing their resilience and improve their livelihoods. In this study, we are looking at a subset of stress tolerant varieties and improved cropping systems for the drylands in Kenya.

In this paper, we present the results of these participatory trials of CSAP portfolios collected on-station and in two representative villages of Makueni County in Kenya. We look at how the farmers evaluate the varieties, in the middle and at the end of the season, and which feedback they give to scientists to fine-tune the technologies. Several descriptive plots of scores given by farmers are displayed and disaggregated by gender and varieties, then more statistical approach (ordinal regression) is explored to understand the socio-economic determinants of scoring and obviously the difference between each germplasm. Finally, we assessed the influence of diverse characteristics of both beans and maize on the overall score given by farmers to compare to scientists' approach, more focused on yield.

2.2 Technologies tested

Several drought tolerant maize varieties (DH02, DUMA43, KDV, TEGO, DH04) were tested with different germplasm of common beans (GLP92, KATEX56, GLP1004, KATB1). In order to assess those intercropping systems and each germplasm individually beyond their yield potential, we implemented a participatory approach which takes into account farmer's perceptions. As stated by De Groote et al. (2013), such a participatory approach is fundamental to understand the large number of attributes that farmers appreciate in their crops, influenced by socio-economic and institutional factors. Based on both on-station and on-farm trials, this paper relies on the data collected in 2016 for the mid-term and the end-term evaluation. Not always collected, those mid-season data allows the assessment of beans just before the harvest, and also maize characteristics that can already been assessed at this stage.

2.3 Study area

The study presented here is part of the PEACSA project (Participatory evaluation and application of portfolios of climate smart agriculture practices to enhance adaptation to climate change in mixed smallholder systems of East and Southern Africa), which is part of the CRP (CG wide research program) CCAFS (Climate Change, Agriculture and Food Security). CCAFS was launched in 2011 with 15 climate-smart villages in West Africa, East Africa and South Asia. All the villages are in high-risk areas, which will likely suffer most from a changing climate. Villages are also locations where partners have already established vital links with local communities. Due to funds limitation, PEACSA is being implemented in three of these sites which are; Makueni in Kenya, Lushoto in Tanzania and Rakai in Uganda. Even if data collection are currently collected in 3 countries (Tanzania, Uganda, Kenya), by the time of the submission of this paper, only data collected in Kenya has been cleaned and assessed. This paper therefore covers Makueni only but the rest of the data will also be analysed and published later.

Makueni district is one of the 36 drylands districts of Kenya (Arid and Semi-Arid lands (ASALS)) and more specifically one of the 6 semi-arid districts. Those regions are characterized by hot and dry climate and rainfall ranging from 200 mm per year to 600 mm per year (Lemba, 2009). Semi-Arid regions (rainfall >400 mm per year, distributed in a short and a long rainy season) are a mixture of agro-pastoral farming systems including extensive irrigated areas, wetlands and national parks. Farmers mainly rely on family labour, land, and oxen-pulled plough and own-saved seed as the most important resources and agricultural production are largely semi-subsistence ones (FAO, 2009).

Beyond biophysical consideration, the selection of this district to implement our participatory trials was due to the high level of food insecure households in the region. As underlined by Lemba (2009), 75% of farmers face very low yield and rely only on rationed food from relief agencies. Makueni County has been the focus point of many food security interventions and thus we had the opportunity to rely on previous household diversity study to build our study and select villages for on-farm trials. Last, but not least, CGIAR centres (CIAT, CIMMYT) along with ICIPE center, have developed a strong partnership in this region of Kenya, and this network were the keystone of this participatory trial implementation.

2.4 Participatory trials and data collection

The implementation of the trials and the evaluations involved several stages of discussions with the farmers and participatory selection of the technologies to be included. Focussed group discussions were conducted where scientists from partner organisations presented the CSAP technologies they had to the farmers. The farmers selected what they wanted to implement at their villages and also at the on-station trial.

An on-station trial was implemented in the Agricultural training Center in Wote. Because of the systems approach to the trials, maize varieties were tested with intercropping with beans and pigeon peas, and the vice versa was also implemented. Five maize varieties were intercropped with one bean variety and one pigeon peas variety while four beans varieties and two pigeon peas varieties were intercropped with one maize variety. Regarding the important surface available, we decided to design the trials with 3 replications. Each replication was a random succession of 5 blocks:

- A : Push-pull technology
- B : five maize varieties intercropped with one variety of bean
- C: four beans varieties intercropped with one variety of maize
- D: two pigeon pea (*Cajanus cajan*) varieties intercropped with one maize
- E: Five maize varieties intercropped with one pigeon pea variety

Thanks to several field days where farmers had the opportunity to see each varieties and combinations of them, we were able to select seven farmers for on-farm trials. Based on both farmers' willingness to run the trials, and representativity of villages based on household typologies, Itunguni, Kikeneani, Kwamboo, Sinai, Kona Baridi, Kithoni and Soweto villages were selected. In on-farm trials, only one replication was implemented, and fertilizer was given to the farmer, along with seeds selected according to results observed on on-station trial. Since the varieties used in the trials are not new, both the on-farm and on station were implemented simultaneously, but the on-farm was a reduced set of the on-station trial. We did not have push pull included in the on-farm trials.

Regarding farmer's evaluation of trials, the first important step was to collect their own criteria to evaluate both maize and varieties. Indeed, in order to widen scientists' criteria mainly based on yield and disease resistance, we had to meet several times with farmers communities to understand their criteria, and determine which of them will be able to be determined with on-field evaluation. For instance, potential for transport and storage, or even milling potential, were not possibly measurable on the field.

Those meetings led to a list of 15 criteria for maize and 18 for beans to be assessed during evaluation. Some were to be exclusively evaluated during the mid-season evaluation and other during the end-season evaluation. Most of them were observable during the two rounds of evaluation. In the results section, we will see their weight in the overall score of each variety by farmers.

The mid-season evaluations for the on-station trial at the ATC in Wote was conducted on January 20, 2016 had 96 participants (46% female). The mid-season evaluations for the on-farm trials was conducted on January 19 and 21 2016 for Itunguni and Kikeneani respectively. There were 30 participants at Itunguni (73% female) and 24 at Kikeneani (49%

female). It must be noted that it has been asked to organizers to respect as much as possible a 50/50 proportion of female- and male-participants.

All criteria were carefully translated from English to both Kiswahili (national language) and Kikamba (local dialect) to ensure that they were well understood by every participant. Before going to the field, farmers were also asked to fill the first part of the questionnaire with their household and farming system main characteristics. They were assisted to fill this section by a team of trained enumerators. They were then taken through the evaluation criteria where every aspect of evaluation as well as the scale was explained. For the actual evaluation, farmers were divided into sub-groups, each one led by an enumerator. Farmers were also asked to identify and record their first three favourite blocks and the favourite plot within the selected block to be able to provide a synthetic feedback on the field. It was impossible for the on-station trial to do it *in situ* due to complexity linked to replications. After the evaluation, summary session, followed by the sharing of refreshments was conducted. Transport allowance of Ksh 300 per farmer was paid for the participants at the on-station field evaluation.

The on-farm evaluation was conducted in a similar fashion as the on-station. However, because there were no replicates in these trials, we could engage the farmers directly in discussing the evaluation. As we will see in the next section, scoring data are very specific type of data which require *ad hoc* models to be properly explored. Since we had no replicates and blocks in the on farm trials, the participants were asked to identify and record their most preferred three out of nine plots. Because the evaluations took place in the village, and only farmers from the village/group were invited, transport allowance was not paid but refreshments were provided after the evaluation.

2.5 Ordinal regression with random effect

As explained by De Groot et al. (2010), participatory approach of varieties selection has focused for a long time on ranking varieties as it was then straightforward to conclude on the “preferred” seed and design adoption recommendation scheme. Nonetheless, ranking become very challenging to analyse when more than 3 varieties have to be ranked, and only provides a relative perception of varieties when score gives an absolute value (Coe, 2002). In Kenya, we used an alphabetical scoring from A: very good to E: very poor, which are the same codes used in the local school grading system, and farmers are used to and comfortable with. When entering the data, the scores are converted to numerical data (A=5, B= 4 and so forth). These numerical scores are, however, ordered categorical data, not interval or ratio variables (Stevens, 1946) and can therefore not be analysed with classic statistical methods such as means and standard errors. This type of data can, however, be analysed with median and frequencies, and with ordinal regression (Coe, 2002; De Groote et al., 2010).

In this paper, we implemented an ordered regression model to determine the determinants of farmer’s score of maize and beans varieties. Further, since the same farmers evaluate different technologies, their scores could be correlated, violating the basic assumptions of the regression model. This can be solved by adding a fixed or random effect for each farmer (Greene, 1991). Therefore, our model considered both fixed effects (socio-economic and agronomic variable) and random effect (farmers), and is called cumulative mixed model. It was implemented thanks to function clmm of the package “Ordinal” (Christensen, 2012) in R. (3.0.0).

3 Results and discussion

3.1 Graphic exploration

Graphical explorations displayed in Figure 1 and 2 are basic examples chosen to demonstrate that multiple criteria need to be considered in the analysis of overall evaluation of maize and bean varieties. In Figure 1, sites, gender and varieties are crossed with overall evaluation of the later. We can see that crossing these effects is interesting for many cases, e.g. DH02 variety received high scores in Itunguni while it is mainly negative in Kikeneani. Another example of complexity of inter-crossing effect is the difference of gender distribution: if the distribution between two genders is similar for DUMA in Wote-station, it is very different in Itunguni for the same variety. Apparently, male tends to score very few the best score (5). It is important to note on the vertical axis that effective are significantly different between on-station results and on-farm trials.

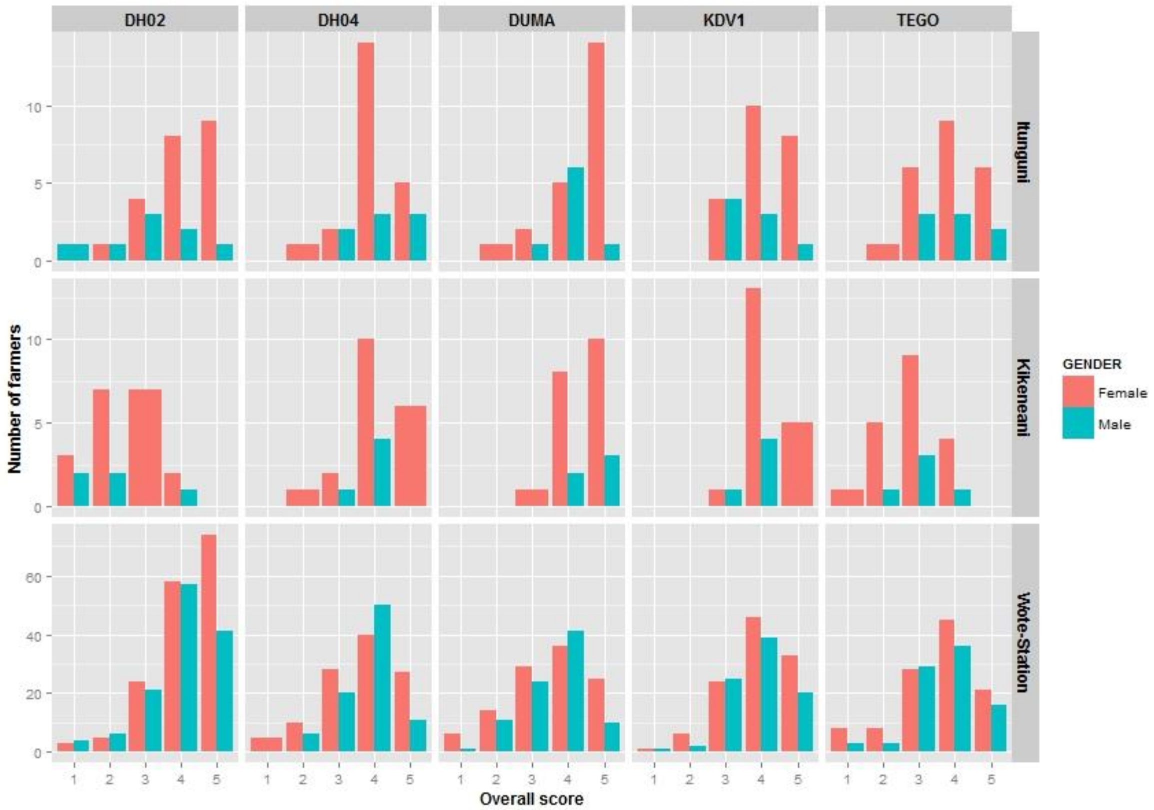

Figure 1: Participatory trials scoring at mid-season of 4 maize varieties in Kenya in 3 sites (gender-disaggregated)

Figure 2 displays the proportion of each score for each variety of maize and beans, regardless of sites or gender. For maize, the pattern is very comparable for the five varieties, and the proportion of score from 1 to 5 very similar. It can only be noted that variety KDV1 have significantly less proportion of lower score. For beans, patterns are also very similar, except variety GLP92 which clearly shows higher proportions of lower scores, and only 10% of farmers gave it the maximum score. Once again, those graphics just shows that all the effects studied in this paper are overlapping and clear trends are hard to visualize, even if they display four dimensions. For these reasons, we developed in the next section a model which allows the simultaneous analysis of all these effects, and compare them to show which ones affects the most the overall score of farmers.

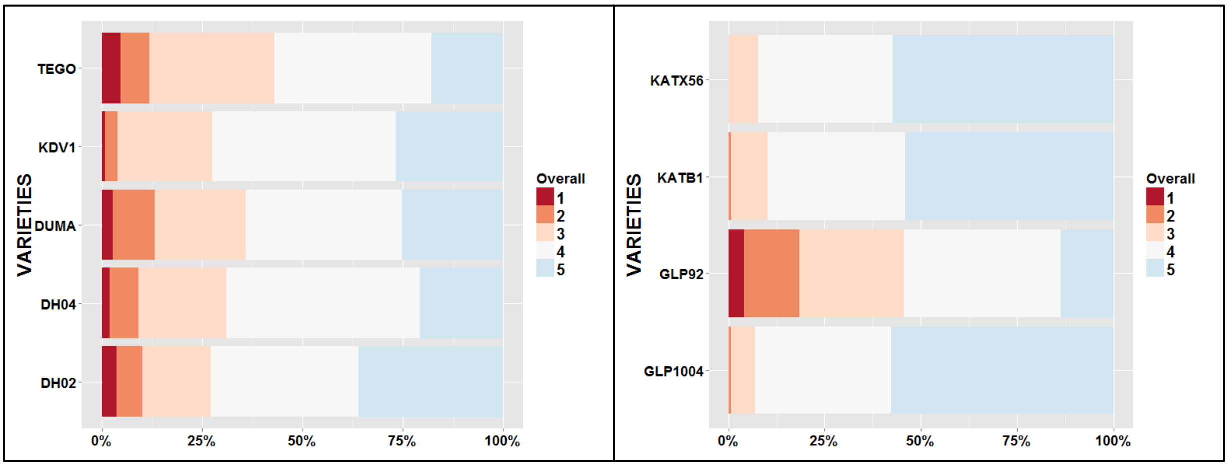

Figure 2: Proportion of each score category (1: very poor, to 5: very good) for five maize (left, at mid-season) and four beans varieties (right, at harvest stage) in Makueni county (Kenya)

3.2 Cumulative mixed model: varieties appreciations and agronomic and socio-economic factors influencing the overall score

Table 1 synthetises the results of the chosen regression model for both mid-term and final evaluation for maize varieties. For mid-term evaluation, we can see that 3 varieties (TEGO, DH04 and DUMA) scored significantly lower than DH02 and KDV1. Although these varieties are all dry-tolerant, we can see that farmers expressed distinct appreciations. A possible explanation could be that these varieties are released after long term station program where maize is tested in mono-cropping systems. Here, by intercropping with several varieties of beans, we assessed an “intercropping potential” of these varieties. In other words, TEGO, DH04 and DUMA are maybe performing very well in controlled mono-cropping systems, but are not suitable to intercropping system. If this hypothesis is confirmed with further research, breeding program will have to include intercropping systems in their varieties performance assessment. Regarding other parameters linked to overall score, we can see that Wote on-station trial and Kikeneani are characterized by lower score, emphasizing the very good trial observed in Itunguni village. Discussion with farmers will allow us to understand the main management parameters which differed between two sites and impacted the trials (fertilizer, weeding, manure, etc.). Finally, it is interesting to note that farmers who already purchased improved maize seed are giving lower score. We can assume that these farmers are used to see maize with high potential, and so were less convinced by these trials to score the maximum value.

Regarding final evaluation, we can see that varieties effect is still significant, and variety TEGO has a significant link with lower score, as shown in mid-term evaluation. In this case, we can conclude that mid-term evaluation was enough for farmers to conclude on their choice to give the lowest rank to TEGO variety. Nonetheless, effect for other varieties emphasized more tenuous differences between varieties, which can only be revealed by a final evaluation. Interestingly, site effect noted in mid-term evaluation didn’t appear in the final evaluation analysis. Combined with the more important effect of varieties in final evaluation, we can assume that varieties fully express their potential at final stage and mask the site effect, only observable at mid-season evaluation. Another difference is the significant effect of gender, with the trend of male farmer to giver lower score in the final evaluation. Further research will be needed to understand what are the characteristics of the maize revealed in the final evaluation which create this distinction between male and female farmers’ perception of varieties.

Among the bean varieties, as shown in Figure 2, GLP92 is scored much lower, significantly, than the other bean varieties. This seed is widely used in Eastern Africa and known to be resistant to Halo blight (common bean disease). Once again, further research will be required to understand why a well-known seed like GLP 92 can get such low scores in intercropping systems while it performs correctly in mono-cropping system. We can also see in Table 2 that bean got higher score in Wote on-station trial, which can be correlated to the labour availability significantly higher in the on-station trial. Gender and socioeconomic variables were found to affect the scores. Men generally scored beans lower than women did. Further gender study needs to be implemented to understand gender disaggregated perceptions of the trial, and specifically why female and male appreciates differently dry-tolerant bean seeds. Table 2 shows that bean scores are positively correlated with farmers’ age. Once again, it is hard to draw conclusion, but we can maybe assume that young farmers are more used to see improved varieties of seed, widely spread in Eastern Africa and then show more discriminant power to rank them.

Table 1. Analysis of the overall score (at mid-season and final evaluation) explanation by varieties, sites, socio-economic and agronomic factors

Group	Variables	Mid-term evaluation				Final evaluation			
		Estimate	Std. Error	z value	Pr(>|z|)	Estimate	Std. Error	z value	Pr(>|z|)
Varieties	VARIETIESDH04	-0.47191	0.157586	-2.995	0.0027**	1.058193	0.177528	5.961	0.0000***
	VARIETIESDUMA	-0.56661	0.160255	-3.536	0.0004***	1.300279	0.191246	6.799	0.0000***
	VARIETIESKDV1	-0.18979	0.156894	-1.21	0.2264	0.521241	0.179792	2.899	0.0037**
	VARIETIESTEGO	-0.89201	0.157589	-5.66	0.0000***	0.364029	0.16608	2.192	0.0283*
Sites	SITEKikeneani	-1.03951	0.349298	-2.976	0.0029**	-0.43767	0.261589	-1.673	0.0943
	SITEWote-Station	-0.59248	0.245976	-2.409	0.0160*	-0.00323	0.193248	-0.017	0.9867
Socioeconomics	GENDERMale	-0.3183	0.183389	-1.736	0.0826	-0.34712	0.158753	-2.187	0.0288*
	AGE	0.009233	0.006661	1.386	0.1656	0.007702	0.005965	1.291	0.1966
	PURCHASED_IMPROVED_MAIZE_SEED	-0.47563	0.209045	-2.275	0.0228*	-0.22937	0.181297	-1.265	0.2058
	NUMBER_OF_CATTLE_OWNED	0.001025	0.005274	0.194	0.8459	0.003352	0.005996	0.559	0.5761
	OWN_FARM_SIZE_IN_ACRES	-0.02804	0.019683	-1.424	0.1543	-0.00827	0.017773	-0.465	0.6417

for maize in Makundi county (Kenya) (Significant at 5%:*, at 1%: ** and 0.1%: ***).

Table 2. Analysis of the overall score explanation by varieties, sites, socio-economic and agronomic factors for beans in Makundi county (Kenya) (Significant at 5%:*, at 1%: ** and 0.1%: ***).

Group	Variables	Estimate	Std. Error	z.value	Pr(>|z|)
Varieties	VARIETIESGLP92	-2.7346	0.2699	-10.1333	0.0000***
	VARIETIESKATB1	-0.2387	0.2513	-0.9497	0.3423
	VARIETIESKATX56	-0.2674	0.2717	-0.984	0.3251
Sites	SITEKikeneani	0.2896	0.4324	0.6697	0.5030
	SITEWote-Station	1.4594	0.3335	4.3755	0.0000***
Socioeconomics	GENDERMale	-1.0367	0.2631	-3.9398	0.0001***
	AGE	0.0274	0.0095	2.8789	0.004**
	PURCHASED_IMPROVED_MAIZE_SEED	-0.0609	0.295	-0.2063	0.8365
	NUMBER_OF_CATTLE_OWNED	0.0007	0.0066	0.1005	0.9200
	OWN_FARM_SIZE_IN_ACRES	-0.054	0.0265	-2.0373	0.0416*

3.3 What criteria influence farmers to evaluate globally a maize or bean variety?

Regression of the overall scores on the scores for the individual criteria show which criteria are important (Table 3 for maize and Table 4 for beans). Indeed, in the on-station trials, the most important criteria focus on production (yield, plant size, etc…). For maize at mid-term and final evaluation, those effects are indeed very significant (yield, number of cobs) but other criteria also appear to be important in the overall scoring. Early maturing, plant height, are also connected to yield, but they can also be indicators of early maize income and biomass for livestock respectively. Overall, nine of the 15 criteria for maize at mid-season evaluation and seven of the 13 for final evaluation significantly affect the overall score, underlining the complexity of farmer’s evaluation of varieties. The comparative analysis of sub criteria’s weight in overall score between mid-season and final evaluation reveals the complementarity of these evaluations. If cobe size and bareness level are significantly affecting the overall score at mid-season (certainly as a proxy to potential yield), they are not anymore significant at final evaluation where yield effect is stronger (directly observable at this stage close to harvest). Obviously, some indicators such as lodging resistance can solely be assessed properly at the final stage, and it is confirmed in table 2. Finally we can see that early maturing, a criteria only used in mid-season, appears as significant at this stage, and emphasize the need to use farmer’s criteria with the distinction of maize development phase. For beans, we can see in table 4 that 13 of the 18 sub-criteria are significantly affecting the overall score, emphasizing multiple implicit criteria used by farmers to assess a variety. Disease resistance and early development also adds to classic yield indicators (pod size, seeds per pod, etc.). The number of significant criteria is here very important, revealing the traditional knowledge to estimate the productivity of a bean variety. In addition, the significant effect of the fuel availability from bean plant shows that expectation of farmers goes beyond pod production. It emphasizes once again the multi-purpose of bean production, from soil fertility to food security and fuel availability.

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Table 3: Ordinary least square regression to estimate the weight of each criteria in the overall score of maize attributed by Kenyan farmers in Makueni county at both mid-season and final evaluation (Significant at 5%:*, at 1%: ** and 0.1%: ***).

Variables	Mid-season evaluation				Final evaluation			
	Estimate	Std. Error	t value	Pr(>|t|)	Estimate	Std. Error	t value	Pr(>|t|)
Crop_stand	0.06703	0.02106	3.1835	0.00148**	0.084905	0.026603	3.191	0.0014**
Plant_height	0.10387	0.02333	4.4528	0.00001***	0.146563	0.027761	5.279	0.0000***
Stalk_thickness	0.04143	0.02383	1.73885	0.08225	0.052913	0.030217	1.751	0.0802
Number_of_cobs	0.07986	0.0249	3.20695	0.00137**	0.086994	0.030739	2.83	0.0047**
Cob_size	0.07114	0.02485	2.86314	0.00425**	0.057905	0.031717	1.826	0.0681
Barreness_level	0.05736	0.01987	2.88707	0.00394**	0.025332	0.024836	1.02	0.3079
Yield	0.16515	0.02546	6.4861	0.0000***	0.252331	0.032155	7.847	0.0000***
Good_tip_cover	0.03059	0.02075	1.47403	0.14067	0.006314	0.026487	0.238	0.8116
Biomass	0.00406	0.02183	0.18583	0.8526	-0.05221	0.026818	-1.947	0.0518
Lodging_resistance	0.02682	0.02228	1.20392	0.22879	0.114389	0.02794	4.094	0.0000***
Stalk_borer_resistance	0.02865	0.02277	1.25818	0.20851	-0.01274	0.028518	-0.447	0.655
Drought_resistance	0.09653	0.01928	5.00607	0.0000***	0.211984	0.020705	10.238	0.0000***
Tillers_development	0.08896	0.01765	5.04131	0.0000***	0.0877	0.022517	3.895	0.0001***
Early_Maturing	0.1212	0.01889	6.41706	0.0000***				
Resistance_to_Foliar_Diseases	0.03431	0.02154	1.59275	0.11141				

Table 4 : Ordinary least square regression to estimate the weight of each criteria in the overall score of beans by attributed by Kenyan farmers in Makueni county at harvest stage (Significant at 5%:*, at 1%: ** and 0.1%: ***).

Variables	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
Pods_Stay_Dry	0.2033	0.0279	7.2913	0.0000***
Yield	0.1789	0.0267	6.6905	0.0000***
Resistance_to_Shattering	0.1451	0.0272	5.3396	0.0000***
Disease_Resistance	**0.144**	**0.0303**	**4.753**	**0.0000*** **
Multiple_harvest	0.1338	0.0372	3.5982	0.0003***
Pod_Size	0.12	0.0279	4.3058	0.0000***
Early_Flowering	0.115	0.0378	3.0407	0.0024**
Open_Canopy	0.1096	0.0249	4.3942	0.0000***
Fuel_Suitability	0.1091	0.025	4.3657	0.0000***
Grain_Size	0.0646	0.0309	2.0894	0.0369*
Early_Maturing	0.0638	0.0264	2.4121	0.0160*
Pest_Resistance	0.0598	0.0228	2.6222	0.0089**
Germination	0.0389	0.0123	3.1587	0.0016**
Non_Climbing	0.0237	0.0172	1.3792	0.1681
Low_Branching_Height	0.0184	0.0217	0.8481	0.3966
Drought_Resistance	0.0117	0.0286	0.408	0.6834
Seeds_Per_Pod	-0.0203	0.0316	-0.6421	0.5209
Number_of_Pods	-0.0227	0.0263	-0.8627	0.3885

4 Conclusion

Our paper shows that implementation of climate-smart practices portfolios, based on innovative inter-cropping systems and dry tolerant varieties, will have to take into account the complex and multi-factorial perception of farmers. Concretely, our study emphasized that TEGO maize varieties was scored lower in both mid-season and final evaluation, and GLP92 was very significantly scored lower within the beans varieties. Beyond varieties, our study emphasized the significant effect on overall score of socio-economic variable such as the age of the farmer, the previous purchase of improved seeds, or trial sites, for both mid-term and final evaluation.

Visual exploration of data and more in-depth econometric analysis emphasized the cross effects of socio-economic and agronomic data on the overall scoring of the tested varieties. To assess the maize-legume rotation, we argue that the mid-term evaluation led in this experimentation is capital to assess the beans before harvest and allows farmers to score them with a wide set of phenotypic criteria. The OLS regression to explain which of the several criteria weighted the most the overall score also shown the same reflection: farmer’s perception is complex and don’t rely on two or three criteria directly focused on yield. Early maturing criteria also appears important for Kenyan farmers in Makueni County and it is both connected to optimization of both crops and early food/ income availability, even if farmers are aware of lower yield from early maturing varieties.

Nonetheless, results presented here must be interpreted with care as we only analysed data for a single cropping season, which was in addition characterized by higher rainfall that the average in the study area. It must also be noted that if mid-term evaluation is crucial to assess legume performance and early characteristics of maize, it also requires to take more time to the farmers and to the extension professionals.

In addition to farmers’ seed perception complexity, our paper shows that climate smart-practices, based on the optimization of farming system resiliency, needs to bring researcher to re-think our breeding program. Indeed, after “dry-tolerant” or “water-efficient” varieties, we should promote the research toward “intercropping-tolerant” varieties. Intercropping research needs to tackle the high complexity of nutrient flow in the soil, but also the socio-economic factors affecting the seed availability, market access and food security. Only by leading such research, climate smart practices portfolio, composed of several dry tolerant varieties and intercropping system, will be adopted by farmers and bring an *ad hoc* solution to increase resiliency of these farming systems.

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